SELF–COMPACTING CONCRETE. A COMPARISON BETWEEN THE WORKABILITY PROPERTIES, DENSITY, POROSITY AND MECHANICAL PROPERTIES

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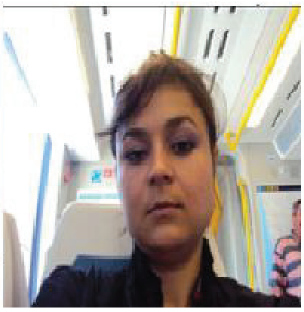

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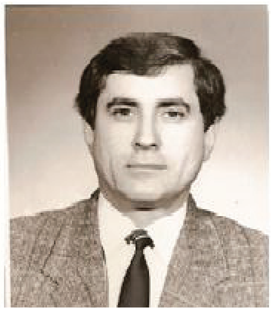

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Abstract: *This paper highlights some connections between the workability properties of self-compacting concrete and the density of the concrete mass and between mechanical properties of compression strength and porosity of concrete samples investigated at 28 days of free curing. Also are* presented properties of raw materials used in this study.

1. INTRODUCTION

The concrete is the man-made material which has the vastest utilization worldwide. This fact leads to important problems regarding its design and preparation to finally obtain an economic cost of the product on short and long time periods. The material has to be also "environmentally friendly" during its fabrication process and also it has to present an esthetical appearance when it is used in the structures. Its success is due to:

a) its raw materials that have a large spreading into the world;
b) the prices of raw materials that are low;
c) the properties and the performances of the concrete that confers it a large scale of application.

Concrete's performances have continuously rise in order to accomplish the society needs. Many studies have been made concerning the use of additives and super–plasticizers in the concrete for passing the frontier of minimum water content for a good workability of a concrete. As a result of this, high performance concretes developed having a superior durability.

Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete.

SCC has many advantages such as the followings:

a) from the contractors point of view costly labor operations are avoided improving the efficiency of the building site;
b) the concrete workers avoid vibration which is a huge benefit for their working environment;
c) when vibration is omitted from casting operations the workers experience a less strenuous work with significantly less noise and vibration exposure;
d) SCC is believed to increase the durability relatively to vibrated concrete (this is due to the lack of damage to the internal structure, which is normally associated with vibration) [1].

2. MATERIALS USED THEIR CHARACTERISTIS

The superplasticizer Glenium Sky 526 used is produced by BASF Company. For this superplasticizer additive the technical data and the chemistry are also presented in table 1 [2, 3]. The manufacturer recommends the dosage to be 0.4 – 1.0 kg per 100 kg of cement.

Characteristics and advantages of this superplasticizer:

- beneficial effect on cohesivity, facilitates mixture pumping and minimizing the risk of segregation,
- improved dimensional stability and reduce the risk of shrinkage cracks,
- maintaining the consistency,
- obtaining a concrete with low viscosity, easy to be compacted and finished,
- obtaining a concrete with high stability under variation of material characteristics.

Table 1: Glenium Sky 526 technical data

Technical data and chemistry	Glenium Sky 526
Primary function	Superplasticizer / high range water reducer
Secondary function	Curing Accelerator
CE mark	Second NP EN 934-2
Aspect	Liquid, brown
Relative density (20ºC):	1,07 ± 0,02 g/cm^3
pH, 20ºC:	5 ± 1
Viscosity (20ºC):	< 100 cps
Chloral content:	≤ 0,1 %
Alkali content	≤ 2.5 % (EN 934-1 / 2008)

The concrete mixtures were prepared with a CEM I 42.5R cement type with Blaine specific surface area (SSA) of 380 m^2/kg and specific density of 3.12 kg/m^3. The same cement was also used in concrete mixtures. In table 2 is shown the oxide composition of this type of cement.

Table 2: Oxide composition of cement (CEM I 42.5 R) and fly ash

Oxide composition, %		
Type of oxide	CEM I 42.5R cement	Fly ash
SiO_2	19.30	59.98
Al_2O_3	5.57	22.87
Fe_2O_3	3.46	4.67
CaO	63.56	3.08
MgO	0.86	1.55
Na_2O	0.13	0.62
K_2O	0.80	2.19
SO_3	2.91	0.35
Cl	0.013	-
TiO_2	-	0.94
L.O.I.	2.78	3.34

The fly ash used in this study is a N fly ash class with a fineness of ≤ 40 % that passes on the sieve 0.045 mm according with European Standards [3, 4]. Its specific density were 2.2 kg/m^3 and Blaine SSA 290 m^2/kg, respectively. The oxide composition of the fly ash is shown in table 2.

3. EXPERIMENTS AND RESULTS

In this study were used granite aggregates. Fine aggregates were within the granulometric range of 0-4 mm, and coarse aggregates in granulometric range of 4-8 mm. We determined the specific density of the aggregates (table 3) and granulometric curves were drawn in accordance with European Standard [5] figure 1 and 2, and in table 4 is shown the oxide composition of granite.

For this study were investigated six self-compacting concrete compositions; three compositions without fly ash and the other three compositions with fly ash. These were tested for slump test to determine the workability properties. Compositions and slump test values are presented in Table 5 and they were conducted in accordance with European standards [6].

Because for concretes, especially self-compacting, properties of compressive strength are the most important at 28 days of free hardening in hydraulic medium, these were careful treatment in this study, the values obtained are presented in Table 6 and were conducted in accordance with European standards [7, 8, 9].

Table 3: Specific density of fine and coarse aggregates

Aggregates	Value of specific gravity (g/cm^3)
Fine aggregates	2,66
Coarse aggregates	2,62

Table 4: Oxide composition of granite

Oxide composition, %								
SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	Na_2O	TiO_2	L.O.I.
70 - 75	10 - 15	2 – 4	2 – 4	0,5	0,5	4 – 6	<0,5	<0,5

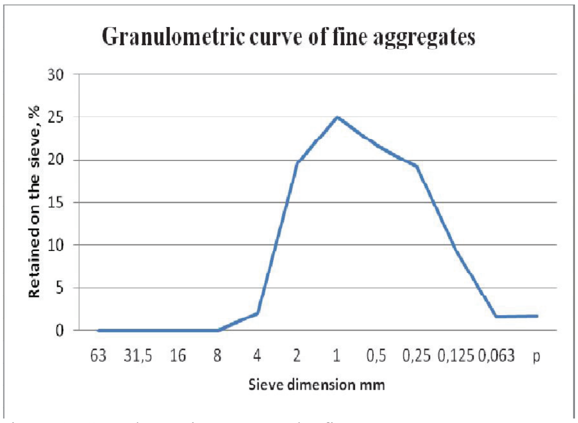

Figure 1: Granulometric curve on the fine aggregates

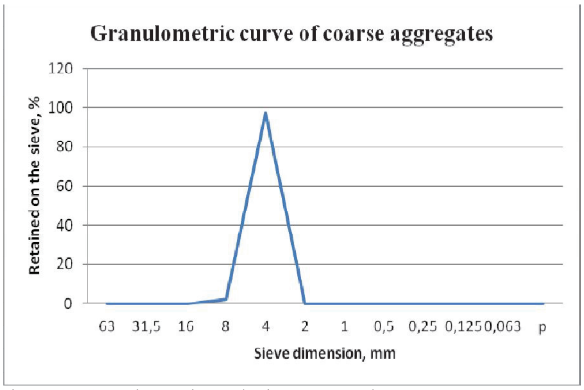

Figure 2: Granulometric analysis curve on the coarse aggregates

Table 5: Self-compacting concrete compositions and workability properties*) No. composition	C1	C2	C3	C4	C5	C6
Cement, Kg/m³	477	477	477	300	300	300
Powder materials (fly ash), Kg/m³	-	-	-	177	177	177
Fine aggregates, Kg/m³	1155	1155	1155	1260	1260	1260
Coarse aggregates, Kg/m³	645	645	645	645	645	645
Water, kg/m³	167	167	167	102	102	102
Aditiv for cement mass, (%)	3	2	2.5	3	2.5	2
w/c ratio	0.35	0.35	0.35	0.34	0.34	0.34
w/b ratio	-	-	-	0.21	0.21	0.21
Slump test diameter (D mm)	787.5	665	710	800	735	600
Slump test high (H mm)	290	273	282.5	290	286.5	271.5

*) *w/c ratio = is the ratio calculated between the amount of water and the amount of cement used in the mix;*

w/b ratio = is the ratio calculated between the amount of water and the sum of all powders quantities used in the mixture, powders such as cement, fly ash,limestone filler, silica fume etc.

Table 6: Compressive strength at 28 days

No. composition	C1	C2	C3	C4	C5	C6
28 days (MPa)	61.8	73.8	70.6	65.5	68.8	75.3

The density and porosity of concrete are given in Table 7. Tests were performed in accordance with European standards [9, 10] and the values obtained

To better understand the data in the tables above, they were introduced in the diagrams from Figures 3 and 4.

Figure 3 is a comparison between the results obtained from the slump test, the diameter and height of the concrete mass spreaded, meaning workability properties, and bulk density determined on samples of hardened concrete. Here it can be see, the compositions C1, C2 and C3 viewing also Table 5, the workability properties are directly proportional to the proportion of superplasticizer additive used in concrete compositions and the density was not caused by the same factor, although compositions in terms of quantity of raw materials used are similar.

Table 7: The bulk density and apparent porosity of the mixtures investigated

Mixture no.	Density, kg/m^3	Porosity, %
C1	2434.13	5.42
C2	2427.56	5.85
C3	2442.59	6.21
C4	2328.12	7.49
C5	2380.06	6.90
C6	2340.54	6.46

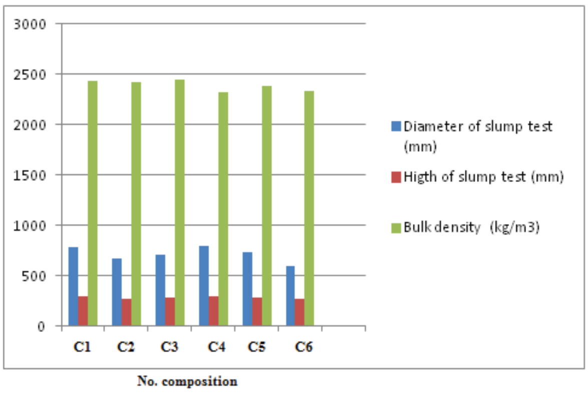

Figure 3: Comparison between the workability properties and bulk density

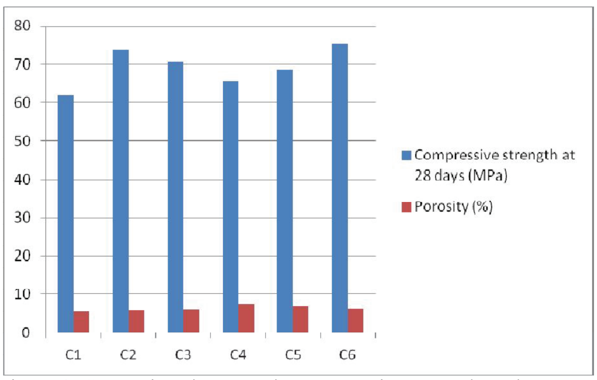

Figure 4: Comparison between the compressive strength and the apparent porosity determinated after the curing period of 28 days

A similar trend can be seen comparing between them, compositions C4, C5 and C6. Workability properties had values that are directly proportional to the amount of superplasticizer additive used and bulk density, as the first three compositions did not comply with the same criteria.

Furthermore, the following comparative densities of 6 concrete compositions it can be seen that the first 3 had a higher density than 2400 kg/m^3, instead the compositions C4, C5 and C6 individual densities have values below this value. One possible explanation may be due to the fact that concrete mixtures C1, C2 and C3 have a quantity of cement 477 kg/m^3, when compositions C4, C5 and C6 had only 300 kg/m^3, of cement, the difference being replaced in terms of volume by fly ash and fine aggregate. Comparison of mechanical compression strength values after 28 days of curing and apparent porosity, illustrated in Figure 4, showed in the first three compositions, that the criterion of proportionality between the values is observed. Compositions comparison between C4, C5 and C6 have revealed a indirect proportionality criterion [11, 12], where a higher porosity, attracts a lower compression strength.

4. MICROSCOPIC ANALYSIS

Microscopic analysis were performed with the microscope SEM (scanning electron microscopy), on samples of hardened cement paste and concrete.

Microscopic analyzes were performed on samples of hardened concrete on compositions C1 and C4. Composition C1 is a composition without the addition of fly ash, and can be seen in figure 5 various forms of cement and aggregates particles, in light colour, bonding together this particles are the hydration products. Figure 6, presents microscopic analysis of composition C4 and it shows the distribution of fly ash particles, spherical in shape. Following Table 5 and Table 7 it can be concluded that due to the spherical shape of fly ash particles, workability, especially of compositions C4 and C5 had good values, considering that water / cement ratio was lower than compositions without fly ash and the water / binder (w/b), which shows more clearly the relationship between the amount of water and powders, is only 0.21. Instead the density of compositions with fly ash was lower due to partial replacement of cement with fly ash (which has a lower density than concrete), which, in turn, has no negative effects on the mechanical strength (Table 6).

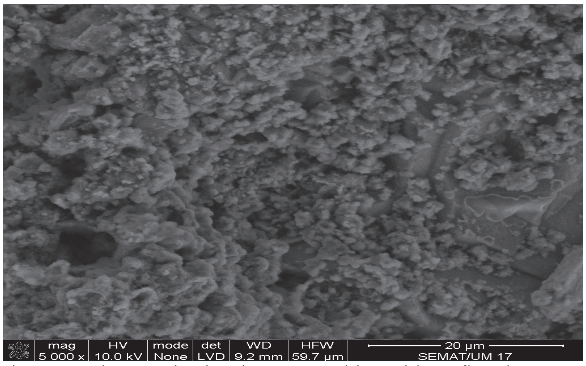

Figure 5: Microscopic view in a composition without fly ash

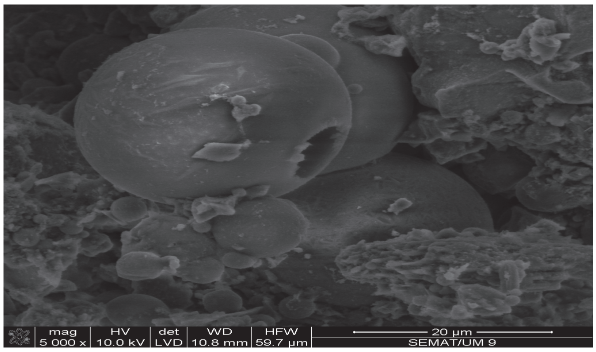

Figure 6: The geometrical form of the fly ash particles in a microscopic analysis

5. CONCLUSION

- Were obtained self-compacting concrete compositions with improved properties of workability and compressive strength, simple compositions and with addition of fly ash;
- Were followed the evolution of mechanical strength as a function of porosity, for the 6 compacting concrete compositions;
- Were revealed by comparison the workability properties as a function of the bulk density of concrete compositions.

6. REFERENCES

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